

Organic Variation Indefinite not Definite in Direction—an Outcome of Environment.

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I.

INTRODUCTION.

Two remarkable utterances have recently appeared from the pens of two of the most distinguished biologists of the day in defense of a theory of evolution radically unsound and differing, as the writer thinks, from that which is held by the majority of evolutionists. The eminence of the names of these authors is sufficient reason to justify a consideration of the view they have advocated. It cannot be supposed that Prof. Asa Gray, of Cambridge, Mass., and Dr. W. B. Carpenter,* of London, would put forward statements all the aspects of which they had not fully considered, and all the legitimate conclusions from which they were not prepared to maintain. Yet both these distinguished writers have enunciated a view of evolution fraught with momentous consequences to biology. So momentous indeed are they that they exclude (if the views in question are well founded) a very large part of the field of investigation now before the biologist from the lawful domain of natural science and relegate it to another department of enquiry.

The nature and direction of organic variation are subjects which have become prominent during the intellectual ferment excited by the publication of the "Origin of Species." As a fact variation is admitted by all evolutionists. It is indeed the cardinal fact on which all theories of evolution do and must depend. And both the writers above mentioned alike admit its reality and its importance. Both allow or tacitly assume that there runs through all organic nature a capability of varying from generation to generation—that under the superficial and obvious resemblance existing between parent and offspring there lie deeper and less easily discerned distinctions which differentiate the one from the other and accumulate in certain directions from age to age. This capacity, manifesting itself in the fact of variation, when encouraged or repressed by the action of natural or other selection has—so Darwin maintained—resulted in the extinction of old and the production of new species.

But while agreeing thus far with most evolutionists the two writers in question express views on variation that are remarkable in the following respect. Instead of proceeding on the ground that variation occurs, or

* These pages were written before science had been deprived of the services of this veteran laborer and leader in biological research by the deplorable accident which caused his death.

may occur, indiscriminately in any direction as lines radiate from a centre, both Prof. Gray and Dr. Carpenter assume or maintain that it takes place only along certain definite lines. Yet further, in their view the changes thus produced in an organism are uniformly of a beneficial kind.

That I may not be subject to the charge of misrepresentation I quote the following extracts from the writers referred to.

In a paper entitled "On an Abyssal Type of the genus *Orbitolites*; a Study in the Theory of Descent," published in the Philosophical Transactions, for 1883, Dr. Carpenter remarks, after detailing the variation exhibited by the forms of *Orbitolites*, "that no exercise of natural selection could produce the successive changes presented in the evolutionary history of the group." "And," he adds, "as all these earlier forms still flourish under conditions which, so far as can be ascertained, are precisely the same, there is no ground to believe that any one of them is better fitted to survive than another." "To me therefore it appears that the doctrine of natural selection can give no account of either the origin or the perpetuation of those several types of foraminiferal structure which form the ascending series that culminates in *Orbitolites complanatus*." "On the other hand there seems traceable through the series a plan so obvious and definite as to exclude the notion of "casual or aimless variation." "Everything in their history shows a well-marked progressive tendency along a definite line towards a highly specialized type of structure in the calcareous fabric."

The significance of these remarks is unmistakable. The writer is evidently maintaining that alongside of the capacity for variation there acts some power guiding the ensuing variation along a definite course to a definite end.

One expression in the above passage calls for a passing remark. In saying that the doctrine of natural selection can give no account of the *origin* of these types Dr. Carpenter appears to have overlooked the fact that no evolutionist attributes the *origin* of varietal or specific forms to this source. Their origin must be sought in variation. Natural selection is only the means of preserving and perpetuating or of destroying and eliminating them. This remark would perhaps be impertinent were it not that other expressions in the same essay also apparently ignore the part played by variation in every accepted theory of evolution. For example, we read, "Those who find in natural selection or the survival of the fittest an all-sufficient explanation of the origin of species seem to have forgotten that before natural selection can operate there must be a range of varietal forms to select from." "No exercise of natural selection could *produce* the successive changes presented in the evolutionary history of the typical *Orbitolites* from *Cornospira* to *Spiroloculina* thence to *Peneroplis*, to *Orbiculina*, to the simple and then to the complex forms of *Orbitolites*."

There is in this passage a singular omission of all reference to the fact

and function of variation, the existence of which no naturalist can doubt, be his explanation what it may.

The second utterance of opinion to which I have alluded is contained in a letter from Prof. Asa Gray, printed in "Nature" (Jan. 25, 1883). The letter itself is written in reply to some remarks made by Mr. G. J. Romanes in an article in the "Contemporary Review" for October, 1882. It is difficult to quote any particular passages in exemplification of the views of Prof. Gray, which are rather implied than expressed. The main point of difference between the two writers is however the denial by Mr. Romanes that "the facts of organic nature furnish evidence of design other and better than any of the facts of inorganic nature," and the maintenance by Prof. Gray that this denial rests on no good foundation. In some passages indeed the latter writer goes apparently even farther than this merely negative position and implies, if no more, that in his opinion variation has been beneficently guided by intelligence. It is difficult to extract any other meaning from the following passage: "The evidence of design may be irresistible in cases where we cannot indicate its limits. We can only infer with greater or less probability according to circumstances and especially according to relation to ends. Better evidence than that of exquisite adaptation of means to ends is seldom if ever attainable of human intention and in the nature of the case it is the only kind of evidence which is scientifically available in regard to superhuman intention. With what propriety then can it be affirmed that organic nature furnishes no other and no better evidence of underlying intelligence than inorganic nature? The evidence is certainly *other* and to our thinking *better*."

It seems impossible to attribute to the author of this passage any intention other than that already expressed; viz.: that alongside of the capacity for variation there acts some power guiding the ensuing actual variation along a definite course to a definite end.

If any doubt yet exists concerning Dr. Gray's meaning, such doubt must be altogether removed by the following extract. In a notice of Dr. Carpenter's paper in the "American Journal of Science," for April, 1884, Prof. Gray says:

"Variation has been led along certain beneficial lines like a stream along certain definite and useful lines of irrigation."

The expression "has been led" is rather indefinite, but can scarcely mean less and may mean much more than I have above attributed to its author. To assert that variation has been led along definite lines implies the coaction of some guiding power. To assert that these lines are always beneficial to the variant organism implies a postulate of vast magnitude and one whose admission is infinitely difficult in face of the phenomena of organic nature.

II.

DEFINITION OF TERMS.

The purpose of this paper is in the first place to examine so much of the evidence of nature on this point as shall be sufficient to show that the

theory of evolution favored by the writers above quoted is not in harmony with the facts, and in the second place to prove that, taken as a whole, the phenomena of nature in the organic world are much more easily explained by the principle of indefinite variation.*

To prevent ambiguity and perhaps misunderstanding it will be well to define at the outset the principal terms that will be employed in this paper.

"Variation" will be here taken to mean all deviations of every kind and degree from perfect resemblance to the immediate parents of the organism whether animal or vegetable. This is the widest signification which it is possible to give and with no other can any useful conclusion be reached. Any limitation can only result in invalidating the argument because it would confine the discussion to a special part of the subject indicated by such limitation. The universal signification to be here employed is also the only fair interpretation that can be accepted by all Evolutionists.

The organism in which such Variation is supposed possible will be called a "Variable." The term is borrowed from mathematics and will be understood to mean an animal or plant possessing the capability of varying whether that capability be latent or active. At any one given instant this power may be always considered latent, time being a necessary element in actual variation.

When from any cause this possible variation has become actual and the organism shows progressive resulting changes, this organism may be called a "Variant." And again when a series of changes is complete or when any particular phase is intended the organism in that stage may be called a "Variate." Thus the term "Variable" will indicate that change is possible; "Variant," that such change is in process, and "Variate," that it is complete, at least for the time, in any given organism.

The term "beneficial" will be employed to characterize any change that conduces to the longer life of the variant organism; this being, for the most part, and other things being equal, the greatest benefit that can accrue to it. I do not deny that there are exceptional cases in which other inherited or acquired advantages may outweigh even this usually supreme one. But almost always a long life may be considered the most conducive to the continuance of the species as it indicates vigor in the individual and increases the chances of multiplication.

The expression "Tendency to Variation," sometimes employed by writers on this subject, either commits an author to the views here opposed (for such tendency must have a cause) or it is meaningless. When variation occurs it must have been antecedently possible. But its occurrence is our only proof of this possibility. Of any "tendency to variation" inherent in the organism we have no proof whatever. For all that we

*The possible assertion that variation is always beneficial in consequence of some cause underlying the constitution of the organic and inorganic worlds and their relation to one another will not be here considered. No writer has, so far as I am aware, ever distinctly enounced it and moreover it will be excluded if, as I hope, I shall succeed in showing that as a fact variation is not always beneficial.

know to the contrary an organism is capable of existing unvaried for any length of time, through generation after generation, without showing the least tendency toward any other form. As well might the mechanician or the astronomer speak of a "tendency to motion" in the heavenly bodies because he sees them all in a state of active movement. For anything that he knows to the contrary all the matter in the Universe may be capable of lying at rest for countless ages. Matter itself has no tendency to motion or to rest. It is absolutely a creature of conditions and of circumstances. So we have reason to believe that organisms have no tendency to variation or to invariance. Changes if they occur, or their absence if they do not, are simply accidents of the environment. The astronomer sees all matter in motion and comes almost instinctively to the belief that the two are inseparable. The biologist sees every organism varying and grows unconsciously into the opinion that variation is a necessary concomitant of life. Both are equally unphilosophical. Absolute rest may be almost inconceivable to the physicist and absolute invariance to the naturalist. Yet both so far as we can know, are thinkable and possible, and both may form a part of the actual scheme of Nature. We see no ground for the expression "tendency to variation."

III.

VARIATION NOT ALWAYS BENEFICIAL.

In the consideration of this part of the subject it will be manifestly impossible within due limits to even notice any large portion of the facts that bear more or less directly on the question. No attempt will therefore be made to take a wide range. Nor is this necessary for the argument. If sufficient proofs can be adduced to show that in some cases the actual variation is prejudicial to the variant the purpose will be served. Yea, more, in logical strictness if a single such case can be established the advocacy of definite variation in a uniformly beneficial direction becomes futile. For unless such beneficial variation be absolutely constant and unfailing no object can be attained by maintaining its occurrence in any single instance.

I propose therefore to limit myself to the presentation of a few of the more conspicuous instances of prejudicial variation, of which some one or more must during a lifetime fall within the cognizance of all who take any interest in the study of Nature.

I may here remark in passing that of the two authors quoted at the outset, Prof. Gray does not give a single instance in support of the proposition which he is maintaining and that the only one under discussion by Dr. Carpenter is drawn from the lowest class and one of the most obscure in the animal kingdom—the Rhizopods—among the Protozoa.

1. *Variation in color.*—Among the many variations in color constantly occurring among animals is the production of a white descendant from colored ancestors.

Every naturalist knows that among wild land animals, with some few exceptions, this color is exceedingly rare. The cause of this rarity is obvious. In a green world a white individual is very conspicuous. Such an animal has much less chance of escaping from its enemies if pursued, or of capturing its prey if a pursuer, than one whose color is more in harmony with its surroundings. Hence its prospects of living and of leaving offspring are proportionally reduced. And in places where green is not the prevailing color, we find the wild animals dressed in harmony with their surroundings. In the Polar regions and in winter the fur-bearing inhabitants are clad in white. No other livery would give them so good a chance of life. In dry and sandy deserts the prevailing color of the fur of the residents is nearly the same as that of the sand. Nevertheless in the parts of the world that are clad in green, white individuals are frequently produced. And we can hardly doubt that similar exceptions to the prevalent color occur elsewhere. Thus we find white deer, white mice, white blackbirds and white wild horses. But their extreme rarity shows that there is some check to their multiplication. And in asserting that this check is nothing more than early destruction in consequence of their conspicuousness I am not going beyond what has often been observed in cases falling within our notice. "On some parts of the continent," says Darwin, "persons are warned not to keep white pigeons" on account of their liability to destruction by hawks. (*Origin of Species*, 1860, p. 84.)

And when to these disadvantages we add those of deafness, of epilepsy and of other diseases which often accompany the white color in animals, cats for example, we find an accumulating variation which cannot fail of being deeply prejudicial to the variant.* Darwin says, "Cats with blue eyes are almost invariably deaf." He has collected a great number of cases showing the disadvantages to which animals are liable whose hair is partially or altogether white.†

Another instance is afforded by some pet rats kept by a relative of the author's, which were with one exception wholly white. They all recently became troubled with bronchitis or some similar complaint, and the sound of their breathing was so unpleasant that they were destroyed except one. The sole survivor was the rat that was not entirely white. This one, though sharing in the disease, was much less severely affected.

The case of albinos may fairly be cited here. In this form of variates not only is the increased color-risk a source of danger, but the imperfect sight so frequently accompanying the whiteness is almost equally prejudicial.

In regard to the vegetable kingdom similar facts may be given. Every gardener is aware that the white seedlings that so frequently come up, in a field of maize for instance, usually die down and yield no seed. Here, as in the case of albinos among animals, the radical cause of prejudicial

* See examples of this published in various numbers of *Nature*, 1884.

† See "Animals and Plants under Domestication," Vol. i, p. 330.

results seems to be the want of the usual vigor, probably in consequence of arrested development or of imperfect ante-natal nutrition—two of the most fruitful sources of variation:

2. *Variation in strength.*—It comes within the observation of all that among animals great difference of bodily strength exists. This is easily noticed in those that are reared for draught. Though less conspicuous the fact is equally true of the savage species. Now this deficiency of power is prejudicial to the variate. The load which one horse can draw with ease is a severe tax on another. A battle between two wild beasts is decided, other things being equal, to the injury and often the death of the weaker. Indeed the prejudicial effect ensuing upon bodily weakness is so evident that long proof is superfluous.

Nor is the deficiency of mental power any less prejudicial. Every one accustomed to observe animals must have noted great difference in their intelligence. Among domesticated species one individual shows mental power fully entitled to the name of reason, while another, perhaps of the same brood, manifests so little that education is impossible. A well-known horse-trainer once told me that though he never failed to train a horse when he took him in hand, yet there were but few that he could train at all, and that he could, in a very short time, pick out and reject the many with which success would be impossible. Some rats are so cunning that to catch them requires all the craft and skill of the householder. Others are so silly that they walk into the trap the first time it is set, and are killed to their great prejudice. The sagacity of bears in avoiding the snare is sometimes wonderful, compelling the belief that they have mastered its construction and found out how to take the bait and yet avoid the danger. Others show no subtlety of this kind, and are caught and killed with ease. Such tales may be found in any work on the habits of animals, and need not be repeated here. But enough has been said to show that the range of variation of the mental faculties of animals is great, and that while the higher degrees confer much advantage on their possessors, the lower are so far inferior as to be seriously prejudicial.

Though pertinent to the argument, it is scarcely worth the time to point out the frequent occurrence of similar prejudicial variation in the human species where the range of the mental faculties is from idiocy upward. In our present state of civilization this disadvantage is partially and temporarily neutralized by the humane sentiment prevailing in society which counteracts the laws of natural selection as they operate among other animals. Yet all such deficiency of power is seriously and often fatally prejudicial

3. *Variation in the senses.*—Whatever prejudicial effect ensues from deficiency of bodily or mental strength is aggravated when this deficiency takes the form of the absence of one or more of the senses. Yet animals are not infrequently born blind or deaf, and the probable reason why such cases are seldom seen is that the absence is so prejudicial as to be soon fatal.

In the consideration of this subject we must bear in mind that to obtain evidence from wild animals is difficult, because they are not under our supervision. Hence it is necessary in most instances to quote facts from animals kept in domestication. But abundance of cases have been recorded to show that similar prejudicial variation occurs among animals in the wild state.

4. *Variation in form.*—Under this head I may quote the well-known case of the Ancon or otter sheep of Mass., “which originated in 1791 with a single specimen having short crooked legs and a long back like a turnspit dog.” This change in a natural state would have been extremely prejudicial to so active an animal. But under human control the very defect was, for a time, a convenience to the farmer, who found that these sheep could not leap over his fences. Hence he preserved and bred them. But the Merino superseded the Ancon, and without the preserving care of man the latter soon disappeared, as it would have done much earlier in a state of nature.

The once well-known turnspit dog supplies another case in point.

A friend of the writer once had a kitten which was born without any hind legs—a defect which had occurred in several litters dropped by the same cat. It lived for some years to my knowledge, and may be living still. When I last saw it it was nearly or quite full grown. Its difficulty of motion was great. Yet I have seen it get up on a chair, and when it walked it threw up its hind quarters and moved with a series of jumps, much as a boy moves when walking on his hands with his feet in the air. Without the care of man so defective an animal must soon have starved for want of locomotive power.

From the above instances the transition is slight to that of monsters. Indeed the line between these and malformation so great as that last mentioned is not easily drawn. Nor do I care to insist on the distinction. The only obvious difference between them lies in the transmission or arrest of the defect. In most cases malformation so serious necessarily ends with the individual.

Some may feel unwilling to admit the pertinence of monsters to the present argument. But they cannot logically be excluded. They are only the extreme cases in which the variation is so prejudicial that life is usually short and transmission impossible. No department of either the animal or the vegetable kingdom is free from the occasional appearance of these usually inexplicable forms. Five-legged calves, sheep with two tails, two-headed fowls and other such cases of malformation are often announced. And after making all due allowance for mere external abnormality there remain enough instances certified by anatomical demonstration to show that the birth of such monsters is by no means rare.*

“The Museum of Michigan University contains a double-headed milk

* Abundant evidence that the human species is not less liable than others to this kind of variation may be seen on the shelves of almost any medical museum and especially on those of the Royal College of Surgeons of London.

snake (*Ophibolus triangulus*) of which the remainder of the body appears to be perfectly normal. Another case is recorded by Prof. Wyman* of a water snake (*Tropidonotus sipedon*) with two heads and two tails, and a similar case as well as one of a five-legged frog is reported by Mr. Kingsley,† Mr. Ryder also calls attention‡ to a specimen of the pickerel frog (*Rana palustris*) with five limbs or rather an additional pair of hind limbs fused together. This leg had six toes and its digital formula might be written—5, 4, 3, 3, 4, 5.

Among insects such monstrous forms have been observed. "Numerous instances of supernumerary legs and antennæ are recorded. The antennæ are sometimes double but more commonly the legs." Asmuss has collected eight examples and in six of these the parts on one side are treble. "Newport relates that from a single coxa of *Scarites pyrachmon* on the left side two trochanters originated. The anterior supported the true prothoracic leg, while the posterior carried two legs each as well formed as the first."§

"Other deformities occur in the wings. Cases of hermaphroditism are on record in which one wing bears the colors of the male insect and the other those of the female. Sometimes the wings are aborted or deformed."

Most persons who have had much experience in the breeding of animals can recall similar instances.

At a recent meeting of the American Entomological Society a monstrosity was noted in a longicorn beetle of the genus *Acmeops* in which the left front leg has three tarsi. A specimen in the collection of Prof. Riley (*Isosoma tritici*) was also described in which the fore wings are represented by rudimentary pads while the hind wings are fully developed (Science, Dec. 5, 1884, p. v).

Mr. J. A. Ryder has recently recorded similar malformation among lobsters under his observation such as the absence of eyes, partial fusion of two bodies, fusion of the eyes on the median line. These changes were coincident with the stage of gastrulation.||

In lecturing on the denizens of the aqueous kingdom, on Friday last, at the Royal Aquarium, Mr. A. Carter referred to deformities that exist among fish. In 1885 and 1886 he had examined thousands of salmon and trout fry at South Kensington, on their emerging from the ova, and found one case of deformity in every thousand, and one case of monstrosity such as twin and dual-headed fish in every four thousand.¶

Though as said above these forms are usually inexplicable, yet their dependence on the chances of outside conditions in some instances at least is indicated in the following passage taken from Darwin's *Animal and Plants under Domestication* (p. 279).

* Proc. of Bost. Nat. Hist. Soc., Vol. ix, p. 183.

† American Naturalist, Vol. xii, pp. 594, 751.

‡ Zoölogy of Ohio, p. 690.

§ Packard's Guide to the Study of Insects, p. 84.

¶ See American Naturalist, for 1886.

¶ Nature, Jan. 6th, 1887, page 231.

“It is known from the labors of G. St. Hilaire, and recently from those of Dareste and others, that eggs of the fowl if shaken, placed upright, perforated, covered in part with varnish produce monstrous chickens. Now these monstrosities may be said to be directly caused by such unnatural conditions, but the modification thus induced is not of a definite nature.”

It is not by any means unlikely that the indefiniteness to which the great naturalist here alludes is a mere consequence of our want of knowledge of this obscure subject and not inherent in nature. The recent experiments of Warynski & Fol, as quoted in the *Journal of the Royal Microscopical Society* (June, 1866, p. 401), tend strongly to confirm this opinion. These zoölogists have succeeded in producing double hearts in chickens by artificial means. The mode of procedure is as follows: “The blunt edge of a scalpel is carefully and lightly drawn backwards along an embryo between twenty-four and thirty-six hours old from just behind the head without injuring any tissues. If all goes well the embryo will continue to develop normally with the exception of possessing two hearts.” The authors quoted were also able to produce other abnormalities in a similar manner.

In the absence of any evidence to the contrary it is more logical to infer that all such cases owe their origin to similar causes, antenatal accidents, not yet discoverable.*

Turning now to the vegetable kingdom we find monstrous forms by no means rare. Not seldom among wild plants the botanist finds flowers in which one portion is hypertrophied to the injury or the atrophy of another or of others. When this atrophy includes the essential organs, such as the anthers or stigmas, it results in sterility and the extinction of the species along that line. Human selection has enormously increased this form of variation. Most of the double flowers of the gardener are monsters to the anatomist. The showy double corolla is obtained at the cost of more important though less conspicuous organs. To quote special cases is here needless. Abundance of them will occur to every naturalist or may be found in works on the subject.

5. *Moral variation.*—Another phase of the subject should not be passed over though any adequate discussion of it is not practicable here. Most naturalists will agree that the moral development of an organism may be prejudicial. Animals born in domestication are not seldom so ill-tempered or obstinate that little or nothing can be made of them. Horses, subject to vice, as it is termed, are sold from hand to hand, lower and lower in the labor scale, until they end by being employed as drudges in the hardest and most menial tasks which exhaust their strength and kill them off before their time. Dogs, too, are often met with which show a disposition so ferocious or uncertain that their owners are compelled to kill them from a regard to their own safety or to that of others. And the testimony of

*For some curious illustrations of another but kindred topic in this connection see a paper on the “Disadvantages of the upright position in man,” by Dr. E. Clevenger, in the *American Naturalist* for 1884.

the tamers of wild animals proves that the same is true among them. The temper of tamed elephants, of tamed lions (so-called), and of other wild beasts indicates a difference of moral qualities quite equal to what we see in the domesticated species. The difference is often very conspicuous in members of the same litter.

The tendency to vice born in many individuals among mankind and growing with age—the inheritance from vicious ancestors—impels its possessor to acts which shorten his days and are in other ways extremely prejudicial to him. The evolutionist may assert that this result is only Nature's way of killing off those unfit to live. The philanthropist may pity them and spend time and labor and money in trying to reform them, and occasionally with success. But both evolutionist and philanthropist thereby proclaim their belief that the moral tendencies developed in these individuals are highly prejudicial and often fatal. They are, however, the outcome of environment of themselves and their ancestors. They are effects of the variability of the organism moulded by circumstances. They are variates whose variation is hostile to their civilized surroundings and leads to extinction. In other countries and among other circumstances they might yet be fairly in harmony with their conditions of life and might live. "The most inhuman monster of crime that ever was condemned by a court and executed by an officer of the law would among such tribes as those of Australia surely pass for the embodiment of all excellences and rise to an uncontested chieftainship" (Bergen: "The Development Theory," p. 178).

It is not relevant to reply that most of the cases here cited are accidents and should not be quoted in proof of the proposition. All such actual occurrences can be logically employed. Accident merely means happening out of the expected course. If accidents happen often they partially lose that character; if they prevail they lose it altogether. If such accidents as those above mentioned were advantageous to the organism they would soon be perpetuated and become the rule. All variations are accidents and their continuance and repetition are dependent on their advantage to the variant. If prejudicial they are soon eliminated and cease.

"Treason doth never prosper; what's the reason?
Why, if it prosper none dare call it treason."

Variation is treason to the original organism. If it can sustain itself it becomes the new organism and supersedes the old one. If not it soon goes down and is forgotten.

These cases therefore are not only relevant but they are the only cases that can be cited. So quickly do all prejudicial variations die out that in the wild state only now and then can they be noted and recorded. Hence the exceptional are the only relevant and valid examples, and to reject them on this account would be to put out of court the only witnesses whose testimony is pertinent and by which the proposition can be established.

So far, therefore, is variation from being uniformly beneficial in its results to the variable or to the variant organism, that in not a few cases that come under our observation it is positively hurtful or even fatal. And these must be only a few out of all that actually occur, inasmuch as they are necessarily taken for the most part, indeed almost entirely, from animals and plants in a condition of domestication.

In domestication also a new and almost omnipotent factor enters the problem—human selection. Now if this beneficial tendency in variation had any existence, it might be expected to show some sign of its action in species under human control. Yet here no trace of it can be detected. When a cattle-breeder attempts to develop certain features it would be evidently beneficial that the stock should vary in the required direction, for failure to do so is quickly fatal. Yet immense care and pains, and the constant elimination of faulty individuals are requisite to obtain success in the endeavor. So with plants. In the attempt to establish a new variety of cabbage or lettuce, years of work are essential and thousands of “rogues” must be pulled from the seed-bed and destroyed before the strain desired attains persistence and perpetuity.

IV.

BENEFICIAL VARIATION AND NATURAL SELECTION INCONSISTENT.

It is further worthy of remark that supporters of the theory of evolution alluded to in the extracts given above can find no use in their system for the subsidiary doctrine of natural selection. Maintaining a beneficial tendency in all variation guiding it in a channel favorable to the variant, they cannot logically admit the directive influence of selection. All variation being favorable, there can be no forms to be rejected. Yet one at least of the writers quoted is evidently an adherent to the doctrine and admits that its action has much influence in determining the surviving individuals. Were directive beneficial variation a fact, all variates must be equally well adapted to their environment though different from each other. So evident is this that proof is needless. Yet Prof. Gray himself appeals to the action of natural selection in his “Darwiniana,” where with a beautiful metaphor he writes :

“Natural selection is not the wind which propels the vessel, but the rudder which by friction—now on this side and now on that—shapes the course. The rudder acts while the vessel is in motion, effects nothing when it is at rest. Variation answers to the wind.”

Directive beneficial variation and natural selection are logical contradictions, and cannot both exist. The former if real must be universal. But I have shown that it is not so. Hence every evolutionist who adopts the theory of natural selection must abandon that of beneficial variation, and *vice versa* every adherent to the theory of beneficial variation is unable to admit the agency of natural selection in any of its forms.

V.

INDEFINITE VARIATION.

The instances already given have sufficiently illustrated the fact of prejudicial variation. Of beneficial variation no evolutionist entertains any doubt. To dwell on it will therefore be needless. But there is a third aspect of the change which must not be omitted. As we have seen, the gain or loss of an organism by varying may be of any degree from that which gives the variate a surpassing advantage and predominance over his fellows to that which leads straight to extinction. In mathematical language the range of variation is from positive infinity ($+\infty$) through zero to negative infinity ($-\infty$). We must consequently admit the existence of variation which confers no advantage and inflicts no disadvantage on the variant—neutral variation it may be called. This neutral variation is an important factor in the problem, though hitherto it has received very little attention. It is capable of explaining some difficulties, of removing some anomalies. Darwin has alluded to it in a single passage: "I am inclined to suspect that we see in polymorphic genera variations in points of structure which are of no service or disservice to the species" (*Origin of Species*, p. 46).

Variation of the kind now under consideration may be often seen among the domestic animals where the struggle for existence is less severe and controlled by other laws than among the wild species. For example, six-toed cats (see "*Nature*" for 1886 and 1887) are a not uncommon though usually a local variety. The peculiarity is freely transmitted. Yet no ill effect seems to attend the irregularity. Indeed if, as asserted, they are good mousers, it may confer a slight benefit though it detracts much from a light and graceful appearance. The same variation is not uncommon among mankind, is there also freely transmitted and is also equally inert in result. The tailless Manx cats may also be quoted in the same connection,* the great range of color in the domestic animals and the manifold shapes of the leaf in many of our garden vegetables which are reproduced with certainty and seem to work neither good nor evil to the plant.

Among wild species the same fact may be noted. Great difference may be seen among the leaves of any species of our forest trees attended with no perceptible advantage or disadvantage. In these cases we need not be surprised to see the variates living side by side with their unvaried ancestors. The red maple of North America is a striking instance. This tree, whose remains are found fossil in the Miocene strata, yet lives in company with its more highly developed and later variates which do not occur in the fossil state.

On this principle I would explain the fact brought forward by Dr. Carpenter of the existence of ancestral forms of *Orbitolites* alongside of later

*In a case that recently occurred under my own observation a single kitten of a litter was born without a tail. It is now nearly full grown and appears to suffer no inconvenience from the curtailment. In a similar way the Manx cats may have originated.

variates. We have but to admit that the changes which occurred to the earlier variable organism were attended with little or no advantage, and that consequently the variable shows no diminution or tendency to extinction by the side of its more specialized variate offspring and the difficulty entirely disappears.

We are compelled to admit variation of all degrees ranging from that which rapidly kills off through that which is absolutely neutral to that which puts its variates at so great an advantage above their fellows that they soon leave them behind and become the "Winners in Life's Race."

VI.

THE CAUSE OF VARIATION.

For a variation so wide in its range as that above described a cause equally wide must be sought. No narrow or arbitrary limits can be set to the cause of a universal consequence. And what more natural or more obvious cause can be suggested than the changes constantly occurring in the environment of the organism? This is of course not a new suggestion, but some writers on evolution seem afraid to carry it out to its full extent. They seem unwilling to abandon the organism to the uncontrolled, confused and seething waves of the sea of physical nature. Yet only in the ceaseless, never repeated tossing of this unresting sea can be found a cause at once sufficiently changeful and far reaching to correspond with the observed changes of the organisms that are borne upon its surface or that live among its waters. Elsewhere in vain do we look for any means of explaining them. All other known natural causes are insufficient and to resort in a difficulty to the unknown and the supernatural is to place the enquiry beyond the pale of science.

In the changes of the physical world therefore and in these alone do we find a cause even presumably sufficient to account for the continual and contemporaneous changes in organic beings. It would be idle to assert that we know the precise mode of action in which the former produces the latter. So new and unexplored is this field that such knowledge is at present impossible. But with every advance we see more and more probability that in the one we have the real and efficient cause of the other. Experiments on the influence of food, temperature, light and other physical agents upon the modification of organisms especially during the formative part of their existence are gradually giving us a mass of information which has already greatly modified former opinions. Some forms once ranked as distinct varieties or even species are now known to be mere accidents resulting from the conditions in which part of their previous existence was spent. Especially is this true with regard to the lower forms.

Time and space will not allow many quotations. One or two must suffice.

"The Mexican axolotl is a tadpole-like animal of considerable size which lives in the water, breathes by gills and is reproduced from eggs.

In its native country this animal is not known to change its form but hatches from the egg into a minute object much like a young tadpole and gradually grows to the form and proportions of the axolotl.

"Now in 1867 the astonishing fact was observed at the Jardin des Plantes that some of these animals cast their skins after crawling out of the water and began a new existence in the shape of a common salamander (*Amblystoma*).

"This change from axolotl to salamander is accomplished in from fourteen to sixteen days and may, it seems, be always brought about in healthy specimens by placing them in shallow water and gradually diminishing the supply.

"Since these axolotl-descended salamanders are of precisely the same species as other salamanders in the western part of the United States it seems certain that these wild individuals are descended from axolotls and it has been suggested that a dry season or a succession of such seasons first caused the change to take place. If so we have here a striking instance where change of climate has produced not merely another species but another genus.*

The following case given by Schmidt in his work "Descent and Darwinism" I borrow from the author last quoted.

"At Steinheim, in Wurtemberg, was once a small lake and in its waters grew countless little shellfish many of them water snails like those of lakes and rivers at the present day. By the appropriation of the limestone dissolved in the water of the lake generation after generation of these snails built up their shells only to let them fall to the bottom on the death of the little inhabitant. By this slow process a layer of shell mud was formed which has, since the deposit was made, hardened into chalk. About forty distinct layers of this chalk differing from one another slightly in appearance may be distinguished and throughout these layers are the perfectly preserved remains of many shells. The shells of each layer remain much the same throughout its thickness but toward the upper limit of each they are observed to vary, so as to approach the form which will be found in the next layer. And not only are the shells of the lowest layer so different that if the intermediate forms had not been discovered they would certainly have been called different species but there are also many among the intermediate forms themselves which if they had been found separated from the others would have been counted distinct."

A figure accompanies this account which exhibits the progressive change from a flat, discoid, planorbiform shell at the base of the deposit to one with a much elevated spire at the summit. A more striking instance of invariance in monotonous conditions followed by variation on the ensual of physical change can hardly be imagined. †

* Bergen, "The Development Theory." See also Buckley's "Winners in Life's Race."

† Mr. W. H. Edwards, of West Virginia, has recently demonstrated similar facts in regard to several species of the Butterflies. He has shown that several forms hitherto considered distinct are in reality only seasonal or other variates. See his "Butterflies of N. America" and his numerous papers on the subject in the "Canadian Entomologist."

Facts of this kind fully and fairly considered (and geology is yearly bringing them in great numbers before us) urge us strongly to the belief that great results are constantly wrought in an organism by physical changes in its environment, and failing evidence of any other agent competent to effect them it is not irrational to ascribe to the same cause all the variational changes. We may then view the organism as plastic material in the hands of its environment, shaped by it entirely and absolutely, and owing its form to its external conditions. Resuming the mathematical illustration the organism is a variable quantity; the physical conditions around it are the causes of its variation; in response to these it varies and after an uncertain period of variance it becomes another—a Variate.

In thus attributing all changes in an organism to changes in its environment we are under no obligation to admit that such changes are or must be favorable. The physical world exists in total independence of the organic. It was before organization and may be after it. So far from serving or aiding it, phenomena lead us to the conclusion that animate nature is, as it were, permitted by and during certain states of inanimate nature. Within certain limits of temperature, light, etc., organic beings can exist. Beyond those limits their existence is impossible. The organism is, so to speak, an accident among its physical surroundings. If these are compatible with life it lives, if not it dies. It exists on sufferance and its existence is lengthened by its power of adaptation—by its variability. If physical changes ensue the organism must adapt itself to them if it can, and continue in being. If it cannot do so it becomes extinct.

Summing up results thus far obtained we reach the conclusion that the doctrine of evolution by variation in a definite beneficial course is not in consonance with the facts of Nature. On the contrary we find that this variation both of animals and plants appears to take place in every direction indifferently and quite without regard to the welfare of the variant. We find further that no cause is known to which these changes can be referred except the accompanying changes in the physical world. To these accordingly we refer them, conscious at the same time that the exact method of their action is as yet largely unknown.

Further we find that the changes thus produced may be either beneficial, neutral or injurious to the variant organism, following, as they do, certain physical laws which are, if the expression may be allowed, totally indifferent to its welfare. In a word, adopting again the language of mathematics, we may say that the Variate is a function of the original Variable dependent on its constitution and the conditions of its environment—that the changes between the Variable and its function, the Variate may be beneficial in a high or low degree; and may lead to its extension and increase; they may be neutral and leave the organism where they found it; or they may be prejudicial and lead to its diminution or extinction. In every case, however, they are necessary consequences of the interaction of the laws of organic nature within and of physical nature without the organism, inevitable, inexorable, fatal.

VII.

A POSSIBLE OBJECTION CONSIDERED.

It will not improbably be objected that in thus attributing organic variation *entirely* to outward agency I am going considerably beyond what can be proved. In the strict sense of the term this is true. We cannot yet demonstrate all the effects of physical change on a variable organism. But we are constantly seeing more and more clearly the immense effects of physical nature on organic beings. And experiments, purposed and accidental, are gradually enabling us to trace special organic changes to their causes in inorganic nature, and thus, as it were, to correlate the kingdoms. A vast field of experiment lies here before us in the attempt not merely to correlate but to commensurate these two, not only to determine what physical changes produce certain organic effects, but to measure both, to estimate and weigh them and at length to predict the organic effect of any given physical cause.

And in this direction modern biological research is tending. The results already obtained warrant the hope that some day the present chaos will be reduced to order, and the changes of organic nature will appear as only the outcome of contemporaneous or antecedent changes in the physical world. A correlative and commensurate scale will be established. Rest in inorganic nature, if possible, will be accompanied with invariance of organic nature, for as said above, no "tendency to vary" exists. On the other hand change in the former, if uncompensated, must as certainly induce change in the latter. The induction is not complete, as no induction ever can be, but the number of instances is already so great and so rapidly increasing that the conclusion cannot be called premature, and while every day increases its probability.

It is true that we cannot as yet show many examples of invariance through very long periods of time. Species die out and others come in. Change is the rule, and we have so far found few exceptions. But the biologist does not stand alone in thus advancing a step beyond the cover of "bald facts." Other students in other departments are accustomed to do the same, and boldly to accept the logical outcome of their observations even in cases where for want of opportunity the crucial experiment cannot be performed. A mechanical illustration will make the meaning clear. The first law of motion is thus expressed by mechanicians: "A body continues in a state of rest or of uniform rectilinear motion unless acted on by some outside force." Yet the mechanician has never seen "a body in a state of rest or of uniform rectilinear motion." His faith is nevertheless unshaken. He argues that as every approximation to the necessary conditions is followed by a nearer approach to such motion if he could obtain perfect conditions, perfectly uniform rectilinear motion would result. The force and justice of his argument are admitted. And on proof like this he builds his science of mechanics, and on this science the works of the engineer confidently rest.

Now conceive an organism as the moving body, the motion of the latter being represented by the specific life of the former. As the moving body travels through space, so the organism travels through time. If unaffected by outside disturbing force the former continues in a straight line. So if unaffected by changes in its environment, the latter remains unvaried from generation to generation, merely changing its position in time as the former in space. Thus each would continue indefinitely, the same in all respects except position, after many thousand years had passed away.

But on its way the flying body approaches some other mass of matter, and immediately feels an influence by which its own motion is modified. So on its way through time the organism comes into a different environment to the influence of which it responds by modification of structure or habits or both. These modifications are the necessary consequences of the changes in its surroundings. In the former case we call them physical, in the latter natural. But in neither do we know anything of the mode of working. Of the "why" and the "wherefore" of both we are equally ignorant. The mechanician sometimes imagines that by attributing the one to "universal gravitation" he has explained it. But he has not. He knows nothing of the nature or of the cause of this universal gravitation. The biologist is not yet sufficiently advanced to generalize variation and give a definite name to its cause. But with this unimportant difference the two are in the same predicament.

The parallel may be followed a step farther. The body moving through space and the organism through time are alike in another respect. The former may be drawn forward and its motion accelerated by an outside force. So the latter may vary and improve under the influence of environment. The former may be retarded and its motion may be diminished or destroyed. So by unfavorable environment the latter may vary in a prejudicial manner until extinction ensues. Yet again the former may, under the influence of the disturbing forces, change its direction without either acceleration or retardation. So the latter may vary in directions which shall be perfectly neutral in their effect upon its welfare, and the new form may be as capable of survival as the old. In both cases the variable is perfectly passive and plastic in the hands of its environment, and the environment is perfectly indifferent to the welfare of the variable. The ensuing variate is an outcome of the conditions of the world around it and must take its chance among them, living if in harmony, or dying if in discord.

In both the above cases the crucial experiment is beyond our reach. To obtain absolutely uniform rectilinear motion there must be only one body in the universe, and no resisting medium. To obtain an absolutely unchanging variable organism there must be no alteration of the conditions of existence. Both are alike unattainable. Yet, as with the mechanician so with the biologist, every approximation brings him nearer to the desired result. The vertebrates are least capable of enduring changes of environment, and land surfaces afford the most variable conditions of life.

Among the vertebrates, therefore, of a terrestrial fauna occurs the most rapid evolution of animal forms. The depths of the sea are the places where conditions vary most slowly. The lowest forms of animal life are least affected by changes of environment. Accordingly among low forms of life, and at the sea-bottom, we find most persistence of type. Illustrations might readily be quoted, but they are needless. The facts are familiar to every naturalist. And reasoning from these facts in the same manner as does the mechanic the biologist argues that could he obtain the requisite unchanging conditions his species would continue unvarying for an indefinite time. Though still variable they would be perfectly invariant.

VIII.

NATURE'S WASTE OF VARIATES.

Nature's variates thus produced take their place among their physical and organic surroundings. With these they are more or less in harmony and in discord. If they can, they live; if not, they die. Nature has no care for her nurselings. She casts them adrift on the world to shift for themselves; to swim if they can; to sink if they cannot. She neither aids nor hinders them. She "cares for nothing." It is a game of "hit or miss;" a method of "trial and error."*

If a somewhat homely simile may be here allowed I will liken the process of Nature in producing variates that are in harmony with their environment to the plans adopted by large commercial houses in making their goods known. Not knowing where their customers can be found they scatter advertisements wholesale over the country. Here we find the name of the firm in a newspaper, there at a railway station, here in a magazine, there on a blank wall, here on the fly-leaf of a book, there on the back of a railway ticket, in one place on the pavement underfoot, in another on the ceiling overhead, now on a handbill forced on us in the street, then around the pages of a railroad guidebook, and sometimes even on the fences and the rocks in little frequented spots. Everywhere crops out evidence of a systematic effort to catch the eye of the public by dint of irrepressible advertising without definite method. Of all these attempts the greater part are doomed to failure. Overlooked by the eager readers of the news-sheet and of the railway guide, trampled under foot by the hasty passenger in the street, read and immediately forgotten by the preoccupied and the thoughtless, they live out their little lives as variates among uncongenial conditions, as seed in stony ground, and pass

*It is to this neglect of her variates that the slowness of Nature's results are due compared with the rapidity with which varieties are obtained by man. A valuable seedling grows up in some out of the way place; man secures it, propagates from it and so perpetuates the variate. But if left to Nature it is probably destroyed and the opportunity lost. Every variety and, still more, every species of Nature's making may fairly be looked on as the result of many experiments undertaken and brought to the verge of success only to be abandoned and fail.

away without remembrance or result. But here and there one out of the great number catches the eye of some one in want of the thing advertised. It brings him in as a purchaser and a sale is made. One success out of a myriad of failures. Yet the purpose is served and the business maintained.

So with nature. She launches into the world her countless hosts of variates—in form, in color, in size, in strength, in bodily and mental qualities. Of these, myriads—perhaps the great majority—die and leave no trace. But here and there an individual possessing characters more in harmony with its environment than those of its ancestors or relations takes advantage of the fact, increases rapidly and finally in the struggle vanquishes them and takes their place. The old organism yields and the variate is called the new species. Such is the method of trial and error employed in Nature if we judge impartially from the facts that meet our eye in every field of the organic world.

Strictly speaking every individual is a variate, for never does the offspring in all minute points resemble its parents. But when out of these hosts of variates all the unfit have been eliminated how few remain. How few even among the human family live to manhood, and how much smaller is the number among the wild species. Nature appears to keep in her workshop moulds of almost every conceivable form, and in these moulds she casts her variates, issuing them broadcast on the world in order to see which can survive. The greater number perish. Only here and there does one prove to be in harmony with its environment and live. But those that perish are quickly destroyed and forgotten—melted down and recast—while the survivors apparently testify by their fitness in favor of special adaptation.

IX.

CREATION BY BENEFICIAL VARIATION AND BY SPECIAL DESIGN.

In this prodigal waste of her variates therefore rather than in their economical production by beneficent variation, we find the clue to Nature's method of creation. She does not make a new variate in perfect harmony with its surroundings and then carefully watch and nurse it into growth and supremacy. She does not study the surroundings in order to make the variate. Still less does she fashion the surroundings to fit the variate. On the contrary her plan is to produce her organisms in vast numbers, and of varied forms and leave them to be assorted by the sifting process of natural selection. The unfit many soon perish. The fit few alone survive and multiply. The result is that nearly all living species thus sifted out are in a harmony so nearly complete with their environment that it seems at first view intentional. And this is the fallacy underlying the argument of the teleologist, whether he belong to the school of "beneficial variation," represented by the writers quoted at the outset of this paper, or to that older school that formerly pressed and whose adherents still press, though

with somewhat diminished confidence, the famous arguments for "creation by special design."

These writers maintain that the adaptation of an organism to its surroundings is a proof of a specially designing intelligence. They say that the countless instances of accommodation discoverable in existing nature and those which may be inferred in past ages could not have come to pass except by intent. It is needless to quote examples. They are familiar to everybody. They have been enlarged on from the days of Paley's watch picked up on a common down to the present day. And even now books issue from the press reasserting and attempting to reinforce this old argument. Yet from the point of view here taken this "argument from design" is entirely illusory and obtains all its apparent importance and its seeming strength from being based on a mere partial view of the subject. The teleologist picks out instances of organisms that are in harmony with their surroundings, sees and studies the many and minute adaptations of the one to the other, and then somewhat hastily infers a special intention in the arrangement. From the examination of a few instances he infers a general rule and asserts that every organism is specially adapted to its environment by intelligence. The inference is natural, obvious and pardonable on a superficial view, but wider and closer observation refutes it. Every organism is in approximate harmony with its surroundings because, as said above, it lives only on that condition. If not it dies. This fact the teleologist fails to see or to appreciate. By him the constant struggle for existence is unseen, the cries of the vanquished are unheard, the thousands that are born only to die of unfitness are unnoticed. Were all these elements taken into account his problem would be less simple and his results less easily reached and less confidently announced. Special intention or design in creation could hardly be affirmed of a world where the greater part of the experiments fail of success.

Returning for a moment to the illustration employed above, the teleologist is in the position of one who seeing an advertisement fall into the hands of a man in need of the article advertised should straightway infer a special design in the advertiser to bring these two together. Not seeing or not heeding the thousands that went to waste he comes to a hasty and incorrect conclusion by imperfect induction. A wider view would give a juster sense of the relation between the failures and the successes and enable him to see the design, for such it may fairly be called in its true light.

For, be it understood that evolution as here defined by no means disproves design. To assert or to imply this would be as illogical as the fault just condemned, but in the opposite direction. That it disproves "special design" is, it appears to me, evident. But design of another kind and of a wider scope, working in quite another fashion—"the method of trial and error"—may yet exist behind all. On this question evolution thus far speaks doubtfully and the biologist holds no positive opinion.

Of one fact, however, he is confident—that all the changes of organic

life are results of unswerving "natural law," the details and modes of whose working he cannot yet trace. Chance at present seems supreme among the transformations which evolution has revealed. But chance is only a name under which we disguise our ignorance. In a world under the action of universal natural law, Chance, that is, causeless effect, cannot exist. Chance in this sense is to the careful student of Nature unthinkable, inconceivable. Every event is a consequent of antecedents and an antecedent of consequents. Order, such as it is, prevails everywhere. The sequence is unbroken. Every existing species is a single link of a chain, one end of which is lost in the distant past and the other end has not yet emerged from the distant future. Every link depends from that preceding it and serves as a point of attachment for that which follows. What the one is the other will be, barring the effect of outside influences, and could the exact nature of the organism be known and the exact effect of environment be determined, it would be possible to foretell the exact nature of the ensuing variate.

But firm as is the faith of the biologist in the existence and ceaseless action of universal law he admits his utter ignorance of that deeper force or of those deeper forces that keep the law in action. This must be determined from the working of the law itself. He must reason back from the law to the underlying principle and determine the nature of the latter from the mode of the former. And if in this profound investigation he finds himself coming to results which clash with prevalent or preconceived opinion, if the law of the universe seems other and harder than poets have feigned, yet sentiment and prejudice should not be allowed to lie as stumbling-blocks in the path of advancing knowledge, nor should the faint voices and dim lights which come to us out of the darkness ahead be disregarded, though they would lead us in different direction from that in which we were wont and wishing to go.

CONCLUSION.

A possibility looms up before the biologist on this view of his science which no other theory can encourage. If all organic changes come about as consequences of changes of environment, why should it be beyond reasonable hope that he may some day be able to grasp the effects of the latter so completely as to foretell the former? Astronomy was once in the state of confusion and ignorance in which biology now lies. The movements of the planets were an unsolved enigma, their paths a tangled maze, their mutual influences a seemingly hopeless chaos. But Copernicus, Kepler, Galileo, Newton, Laplace and Leibnitz arose. The key of the enigma was found, the clue to the maze, the order in the chaos. And now of all the physical sciences, astronomy is the most exact, the most thoroughly under control of mathematical laws. The astronomer, rising above the task of merely recording the past, predicts the future. The movements of the planets are understood; universal gravitation enables him to grasp them, and the subtle mathematical analysis gives him the

means of seizing any one of them, of tracking it through space, of marking its course, of including the varying effects of other globes, and finally, from his complicated formula, he educes a prediction of its place at any moment in the future.

Is it too much to hope that some day the biologist too will rise to the same position ; that some other and greater Darwin will be born to give us a generalized law of variation ; that some biological Newton will arise and enable us to compute the complicated problem which organic beings present in passing through their different stages of variation ? If even now the pigeon-fancier will undertake to produce in a given time a bird with any desired plumage (within possible limits) ; if the cattle-breeder can call into being a variety retaining desirable and excluding undesirable qualities ; if a gardener can develop a new and valuable variety of plant, and fix its characters so that it comes true from seed for many years, why should we not hope that some day the special will become the general, and that what can now be done in a few cases will then be done in all at will ? When the effects of changes in the environment are definitely known and traced back to their special causes, their direction and amount determined and their condition so fully understood that they can be reproduced at pleasure, then will the material be in our hands for the final generalization. Is it too sanguine to hope that a biological analysis will then be invented and perfected as mathematical analysis has been perfected, and that the biologist, armed with this new engine of investigation, will be able to trace the past evolution of organisms to its causes in the organic world ? And, bolder still, may he not venture into the future, seize in the grasp of his Calculus any variable organism, and involving in his formula the successive conditions of its environment, trace it through its complicated changes during its period of variance until his equation yields up the function—the variate—at the end of any desired interval, exhibiting new characters and forming a new species ?

Is such a prospect, though distant, altogether visionary ? May we not hope some day to solve the great evolutionary problem ? Given, a variable organism and the conditions of its environment during a certain time, to determine the consequent changes.